Utilizing Petrophysical Attributes to Optimize Performance of a Horizontal Drilling Program*

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Abstract

Petrophysics enables focused well completions, reservoir modeling, assessments of OIP and EUR, zone ranking, and identification of horizontal drilling landing points, thus facilitating efficient use of capital. A vertical drilling program contributes significantly to the technical database. By Integrating whole and sidewall core data, such as GRI, XRD, and TOC measurements, critical sideboards for the interpretation of wireline logging data can be achieved. Measurements of compressional and shear acoustic data for generation of rock mechanical properties also plays a key role in the petrophysical interpretation.

With 95% coverage of Garden City acreage with 3-D seismic and greater than 50% coverage with high effort proprietary 3D data, Laredo is correlating seismic attributes and petrophysical characteristics to determine regional rock features. With all this technology added to the Laredo tool box, comprehensive analyses are utilized to create a strong horizontal development plan and maximize shareholder value via a growing list of high performing wells.
Utilizing Petrophysical Attributes to Optimize Performance of a Wolfberry Well

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Petrophysics supports well completions, reservoir modeling, assessments of OIP & EUR, zone ranking, plus identification of horizontal drilling targets, enabling efficient use of capital.
Petrophysics Key Points

- Integration, Integration, and more Integration
- Get the correct logging data!
  - Laterologs will read different than Inductions (50 year issue)
    - *You just might walk away from a discovery well*
  - Minimally Triple Combo...Dipole sonic & FMI very helpful
- Whole and sidewall core data provide *critical constraints*
  - GRI, XRD processes (always include quality control checks)
  - Shale properties (TOC, gas analyses, etc.)
- Optimize well placement and completions for efficient hydrocarbon recovery
Permian Basin: Present Day

- **LPI acreage**
- **Cline deposition axis**
- **Wolfcamp deposition axis**
- **Present day axis**

Map showing:
- Delaware Basin
- Midland Basin
- Eastern Shelf
- Quachita - Marathon Overthrust

Scale: 0 - 100 miles
**Vertical Wolfberry program**

provides science/data for horizontal program tool box

Vertical Program Supports Science Gathering
Science Enhances Value

- Cores
- Logs
- Reservoir characterization
- 3D Seismic

Optimize development plan - maximize shareholder value
Key Shale Rock Play Attributes

Integration of the shale petrophysical attributes has a direct correlation to the performance of a well

- Mineralogy (Brittleness)
- Porosity/Permeability (Rock Quality)
- Organic Richness (TOC)
- Thermal Maturity (Ro)
- Burial Depth
Garden City Data Inventory

- ~3,400’ Whole core in objective section
  - 13 Whole core
  - >650 SWC samples
- 34 Single zone tests from objective section (Spraberry to Ellenberger)
- >8,000 Conventional open-hole logs
  - 228 In-house petrophysical logs
  - 96 Dipole sonic logs
  - Fully Core-calibrated
- 774 sq mi 3-D Seismic
  - 95% Coverage of Garden City Acreage
  - >50% of Seismic Inventory is High Quality, Proprietary 3D Data
Integration of Core, Petrophysics and Production Data Defines Resource Potential

Comprehensive Core Sampling & Data Analysis
Conventional & Unconventional Reservoir Lithologies

Log Data QC, Statistical Integration of Core and Log Data,
Attribute Analysis Computations & Volumetrics

Analysis of Source Rock Geochemistry Data for
Maturity, Richness, Burial\Thermal History and HC
Volumes Generated

Volumetric Summaries and Zone Rankings

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<th>Volume Rank</th>
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Induction and Laterolog Resistivity Comparison

Laterolog and Induction Tools read shales differently.

Shale alteration due to fresh drilling mud invalidates the Laterolog data, compounded by anisotropy and resistive clasts.
Laredo’s Proprietary Analysis

Basic Industry Log Analysis + Cores / Science = LPI Proprietary Analysis

Open-Hole Logs + Core sections = LPI Proprietary Analysis

Advanced LPI Proprietary Analysis

Core data + rock data = LPI Proprietary Analysis

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Understanding Fracability is a Key

“Fracability” = brittle shales that hydraulically fracture during completion work the best

ROCK MECHANICS

Calibrated dipole sonic to our data

Fig. 6—Calculated curves of transmission coefficients for plane compressional and plane dip-polarized shear waves across an infinitely thin lubricated crack in an infinite medium (Knopoff, et al.).
Understanding Fracability is a Key

“Fracability” = brittle shales that hydraulically fracture during completion work the best

ROCK MECHANICS

Calibrated dipole sonic to our data

Log Data from multiple vertical wells with 300’ Cline thickness across acreage position

Brittleness derived from proprietary log suite including dipole sonic data

Better Well Performance

Poorer Well Performance

Increasing Britteness

Increasing Water

(BVW = POROSITY * SW)
Science Impact to Lane Trust-C/E-42-2HL

• Based on analysis of the advanced log suite
  ▪ Highest HPV in the interval
  ▪ Most brittle rock in the interval
  ▪ Low frac gradient for optimal stimulation
• Landed lateral in Lower Wolfcamp shale
• Well tested 1,217 BOE/D average 30-day IP
Example: Permian Shale Petrophysics
Application to Horizontal Program

Prime Landing Point for the Upper Wolfcamp (high recovery)

Optimal Landing Point for the Middle Wolfcamp (medium recovery)

Landing Point in the Middle Wolfcamp based on Vertical Spacing (lower recovery)
Applying Fracability to All Proven Zones

- Log brittleness helps in targeting all four producing horizontal intervals
  - Brittleness is a function of clay and water content
  - Brittle rock targeted in landing laterals
- Britteness predictions assist in frac design
Brittleness Takeaways

• The role of rock brittleness and bulk volume water, along with other mechanical properties appear very significant

• Map wireline developed mechanical properties
  • Poisson’s ratio
  • Young’s modulus
  • Brittleness

• Tie seismic expressions to these same mechanical properties
  • Fully describe regional characteristics

• Integrate these data for targeting horizontal wellbore placement and grouping completion stages via horizontal stress measurements
Seismic Expression of Petrophysical Properties

The “Horsemen”

Brittleness

Fracture Density

HPV

Product of the Horsemen “Sweet Spot” Volume

TOC

Porosity

Mud Log Shows
Summary

• Core constraints determined for Wolfcamp, Cline and Atoka-WDFD (*induction logs key to consistency in fresh mud*)
• Refined frac gradient/brittleness model
• Petrophysical presentation for completion design
• Optimum evaluation requires GR /NEUTRON /DENSITY /PE /RES /DIPOLE SONIC to generate mechanical properties
• *End result is growing list of high performing horizontals*